<% strPageTitle = "Essentials of ECE" CreatePageHead %>

What every EE and CompE needs to know

This is a minimal list of material, in the electrical and computer engineering technical areas, that we believe is relevant for the long-term success of electrical and computer engineers. It is intended to be a MINIMAL list; that is, not what is *good* to know or *might possibly* be useful or is useful for *some* engineers, but knowledge that the lack of which would *very likely* hold our graduates back in their careers. It is a list of what EE and CompEs specializing in areas *other* than that specific area minimally need to know to work effectively in their *own*, different, specialties. (That is, what every signal processor needs to know about semiconductor devices; what a control theorist needs to know about computers; what a solid-state device engineer needs to know about signal processing, etc.)

[Topics in brackets have been proposed but not yet confirmed by the full Committee.]

Systems

Circuit and system theory

- Voltage, current, resistance (dlj)
- DC, AC (dlj)
- Resistive circuit as set of linear equations (KVL, KCL) (dlj) (nrs)
- Thevenin and Norton equivalent circuits (nrs) (?/dlj)
- Linearity, time-invariance, and superposition (dlj)
- RLC circuits as linear time-invariant system (dlj)
- Causality (dlj)
- Differential equation models of L, C (dlj)
- Complex variable description of circuit DEs (dlj)
- Frequency/Fourier transform (dlj) (sah) (jj)
- Bode plots (plc) (/dlj)
- [Decibels jba)]
- Phasors (jj)
- Fourier series and harmonics (dlj)
- Circuit as frequency filter (dlj) (nrs)
- Relationship between pole-zero locations and time and frequency response (nrs) (?/dlj)
- Sinusoidal signals (dlj)
- Convolution concept (dlj)
- Modulation (dlj) (/sah)
- AM radio as upconversion and downconversion via modulation (dlj) (/sah)

Digital signal processing

- Sampling idea (x(n) = x(nT)) (dlj)
- Sampling theorem (>2 for bandlimited signals; sincs) (dlj)
- Anti-aliasing and reconstruction filters (dlj)
- Signals digitized by sampling and quantization (dlj) (/sah)
- Discrete-time frequency (dlj) (/sah)

- Difference equations as digital filters (dlj) (/sah)
- DFT is samples of continuous frequency (dlj) (/sah)
- FFT computes DFT fast (dlj) (/sah)
- Basic spectral analysis (dlj) (/sah)
- Poles inside unit circle = stability (?dlj) (/sah)

Control theory

- Concept of feedback
- Control system diagram (plant, controller, feedback) (dlj)
- Control system changes system output, dynamics (dlj)
- Poles in LHP = stability (dlj?) (plc) (/sah)

Communication theory

- Modulation of analog signals on a carrier (dlj)
- [Basic digital modulations (dlj)]

Probability and statistics

- Random variable (dlj)
- CDF, pdf (dlj)
- Gaussian, uniform, exponential/Poisson densities (dlj)
- Mean, variance (dlj)
- Noise, error as random variable (dlj)
- Probability from pdf (dlj)
- Independence(dlj)
- Basic combinatorics (dlj)
- Basic statistical tests, p-value, statistical significance (dlj) (/sah)
- [Physical sources and types of noise (e.g., 4kT, thermal noise, shot noise, associated pdfs) (ek,jba)]
- [Entropy (jba)]
- Random processes (ek) (/dlj)

Physics

Electromagnetics

- Maxwell's equations in integral and differential form (btc)
- Forces and basic electromechanics (plc)
- Uniform plane waves (btc) (/sah)
- Behavior of plane waves within dielectric, conducting, and magnetic materials (btc) (/sah)
- Capacitance, conductance, and inductance (btc) [including parasitic (plc)]
- Propagation of a wave through a transmission line (btc) (/sah)
- Impedance matching at the end of a transmission line (btc) (/sah)
- Refractive index (btc) (/sah) (in Physics already dlj)
- Reflection and transmission (jj) (in Physics class already dlj)
- Boundary conditions (jj)
- Constitutive relations (jj) (what are those? dlj)
- Power and energy (jj)

- Polarization (jj) (already in Physics dlj)

Power systems

- How a generator works (ap)
- How a motor works (ap)
- Power distribution system (sah)

Solid-state physics and devices

- Bandgap/threshold voltage/quantum energy levels/excited state concept (dlj)
- LED, solar cell work by converting photon to/from electron from/to excited state across bandgap (? dlj)
- p and n type materials (dlj)
- Free electrons and holes (dlj)
- Depletion zone (?dlj)
- Diode I-V relationship (?dlj)
- Transistor as electrical valve (dlj) (nrs)
- Transistor I-V relationship (nrs)

Circuits

- MOS transistor as ideal switch (dlj)
- Switch idea to make CMOS inverter, nand, nor (dlj)
- Ideal op-amp I/O characteristics (dlj)
- Basic circuit models for nonlinear devices (diodes, transistors) (plc)
- Small-signal model of a transistor and its use in the design of a resistive load amplifier (nrs) (/dlj)
- cascading amplifiers, amplifier frequency response, feedback theory (NRS) (?dlj)
- Power, delay and noise-margins in a CMOS inverter (NRS)
- Some basic transistor circuits (plc) (such as? dlj)

Materials (cl)

- quantum mechanics (cl)
- solid-state physics (cl)
- thermal dynamics (cl) (/sah)
- photonics (cl) (/sah)
- engineeirng materials and processes (cl) (/sah)
- biological materials and processes (cl) (/sah)

Computers

Programming

- Programming in a practically usable language (e.g., C) (dlj, rws)
- Variables, arrays, indices, pointers, conditionals, loops (dlj)
- Functions, parameters (dlj)
- Structured programming and basic principles of software design (dlj)
- Concept of thread (dlj) (/sah)

- Compilation vs assembly (dlj)
- Fundamental numerical methods (plc) (/sah) (/dlj)
- Familiarity with CAD tools, simulation (plc) (/sah) (?dlj)

Digital hardware

- Digital combinatorial logic, standard gates and digital structures (dlj)
- Sequential logic and clocked logic (dlj)
- State machine (dlj)
- Elements of a microprocessor architecture (ALU, PC, registers, memory, busses, sequencer, I/O) (dlj)
- Memory hierarchy, cache (dlj)
- 1s and 0s as voltages (dlj)
- Gate delay, rise time, concept of a glitch, critical path (dlj) (/sah)

Software/hardware interface

- von-Neumann architecture (dlj)
- How binary object code controls architecture and executes program on hardware (dlj)
- Physical addresses (dlj)
- Interrupts, how hardware signal triggers software action (dlj)
- Stack and stack-based programming (dlj)
- Cartoon view of what an OS does (scheduling, multitasking, I/O, interrupts (dlj)

Networking

- Cartoon description of IP (dlj) (/sah)
- Cartoon description of TCP (dlj) (/sah)
- Concept of IP address and cartoon view of what a router does (dlj) (/sah)
- Cartoon view of how the internet works (dlj)
- What is a MAC (?dlj) (/sah)

Laboratory

- How to read an oscilloscope (dlj) (?sah)
- Familiarity with instruments commonly used (plc) (?sah) (Like specifically what? dlj)
- Measurement techniques (plc) (?sah) (What does this mean? dlj)
- What a datasheet of a component or IC looks like and contains (dlj) (?sah)
- Ability to find and attach power, ground with the proper polarity to a system or device (dlj) (?sah)
- Ability to find the lead corresponding to a given pin number on a component or IC (dlj) (?sah)
- Project requiring system synthesis (dlj) (?sah)

Professionalism and ethics

- A patent gives one the right to prevent others from using and idea for up to 20 years (dlj)
- A copyright prevents others from copying your particular expression of an idea (dlj)
- Engineers are expected to work ethically and professionally so as to minimize danger to the public and to inspire confidence in the safety and efficacy of their work (dlj)
- The IEEE code of ethics (dlj)
- A professional engineer's license is required for a few specific types of ECE jobs (dlj)

ECE facts, history, and culture

- John Bardeen invented the transistor, won two Nobel prizes in physics, and was a professor in our department for many years (dlj)
- Jack Kilby, a UI ECE alum, invented the integrated cicuit
- Correct way to solder (dlj) (?sah)
- Know what a printed circuit board is and does (dlj) (?sah)
- IC fabrication as photolithographic process (dlj)
- Know that a battery is a DC source of a specific voltage (dlj) (?sah)
- Electrical power is 60 Hz, 120 V AC in the US, may be different elsewhere in the world (dlj)
- 540-1600 on AM radio means kHz frequency (who?)
- 87.8-108 on FM radio means MHz (who?)
- FCC makes rules about radio spectrum usage; there are rules (dlj)
- All electronic equipment emits and picks up unintentional "electro-magnetic interference (EMI)" (dlj)

Comments

"In teaching my experimental 398 course (Intro to Speech Technology) I was truly surprised to find that about half the students had minimal or no knowledge of programming or in some cases even of basic computing. The students come from a wide set of areas -- one does power systems -- so I would expect some variation, but not the wide variation that I see. ... To me computer literacy is both essential to anyone in a technical field, and means more than just knowing how to use MS Office and a few GUI-based applications in one's own area of interest. So if I had to make one recommendation it would be that we look carefully at the computing requirements for the UG curriculum and possibly add or revise courses accordingly." (rws)

"These topics are accompanied by mathematical skills in vector algebra, line integrals, surface integrals, volume integrals, curl, divergence, gradient, Laplacians, and phasors." (btc)

From the Power area

"In [the power systems] field one could be a very successful electrical engineer in the power field and need no knowledge about transistors, diodes, and other semi-conductor devices." (TJO)

"What does a generalist in EE or in CompE look like? My personal feeling is that a generalist in EE should know basic circuits (dc, ac, transient), Maxwell's equations and their meaning and use (including basic electromechanics as well as fields and waves), key math tools including Fourier and frequency-domain methods, modulation and signal processing basics, basics of computer system structure and microcontrollers, the operation and function of typical semiconductor materials and devices, and principles of feedback." (PTK)

"Presumably a recent grad should be able to use an op-amp or D/A and A/D converter, use a simple microprocessor in an application, understand why high-speed circuits radiate noise, know why wideband modulation is important, and have some notion about what sorts of problems are easy and what sorts are hard." (PTK)

"A power system engineer can't really function if that person has not internalized the functions of a transformer or the basic field concepts of a transmission line. Personally, I think that also applies to a diode or simple rectifier." (PTK)

"I include electromechanics because it is an essential tool for helping an EE internalize Maxwell's equations. I would not leave out ECE 329 -- or ECE [430]. Maxwell's equations to an EE are like laws of thermodynamics to an ME, and we need to teach them as soon as students can handle it. Similar arguments apply to frequency-domain concepts, to computer interrupt processing, etc." (PTK)

PWS to deliver a copy of his curriculum committee document "what every EE should know" that they worked on in 1991.

"We've traded fundamentals for tech electives. This caters more to specializing (note medical specialists are paid well), which itself is not bad, but we may need to require some more fundamental courses that students are unlikely to take as electives." (PLC)

From Chang Liu

Also, I suggest our students not only need to know the n elements we listed, but also the permutative n! connections between these elements. (CL)

I recognize that "materials" does not fall under the jurisdiction of any specialized area committee - but I think it is the job of the departmental curriculum to look at things that may fall through cracks. (CL)

I also recognize that we have a very strong department and very highly sought graduates as is, by keeping the status quo. However, I think the ambition of our department should be to create leaders. (CL)

I strongly suggest that the curriculum committee chair discuss the motive for the curriculum overhaul to the general faculty at the next departmental faculty meeting and seek broader input. I hope we keep the momentum of this initiative going. (CL)

Yesterday I heard on the radio that Cisco is going to create 4000 high end R&D jobs in India. Cisco in some essence is trying to be a Chinese compny or an Indian company. Leaving the politics of job outsourcing aside, this story illustrate the fact that US can not sit comfortably assuming the high end, high paying R&D jobs will be kept in this country. Our students will be facing competition from India and China more directly. To maintain their advantage, they must be leaders and have strong fundamentals. Otherwise they would be expensive and less trained, and out of a job.
If anything, this kind of story shows that the competition is becoming global, interdisciplinary, and intense. This is a good time to talk about changing curricula. (CL) <% CreatePageFoot %>